GENERAL SPECIFICATIONS

FOR

STEEL RAILROAD BRIDGES

AND STRUCTURES

WITH A SECTION MAKING THEM APPLICABLE TO

HIGHWAY BRIDGES AND BUILDINGS

PREPARED UNDER THE DIRECTION OF

VIRGIL G. BOGUE

CIVIL ENGINEER

BY

ALBERT W. BUEL

ASSOCIATE ON BRIDGES

15 WILLIAM STREET, NEW YORK

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PREFACE.

These Specifications have been written with the purpose of combining such rules, governing the design, workmanship and quality of material, that steel structures built in accordance with them will be first-class in every respect, up to the highest standard of present practice, and at the same time as economical as is consistent with such results.

During the past three years, a very considerable tonnage has been built under specifications not differing materially from these here presented. This included many different types of railroad bridges, swing spans, highway bridges and railroad buildings and sheds. The entirely satisfactory results obtained, without any of the misunderstandings or special interpretations so often attending such work, seem to justify the hope that, rewritten in a general form and revised after three years' use, they may be of some assistance and value to bridge builders. If this is realized, the writer will be fully compensated.

While endeavoring to make them conform with the most recent practice and experience, innovations that have not been fully demonstrated as improvements on older forms have been avoided. Thus, in carrying out this aim, the Cain-Launhardt formula has been retained in preference to the Snyder-Thompson impact formula, but so changed in form that it governs the proportions of all details, including the bearing and shear on rivets, pins and web plates. This is thought to be an improvement on the older form of this formula, and is more rational. It takes into account the ratio of dead to live load, so that, for example, the addition for impact is less in the case of a structure with a ballast floor than where a lighter floor is used. In this respect it is thought to be better than the Snyder-Thompson formula.

The "Quality of Material," specified in Section VI, is first-class in every respect, but such as can be readily obtained in any of the American mills, without extra cost.

The "Workmanship," specified in Section VII, can be complied with by all well-equipped shops. Class C workmanship (see Paragraph 1) is the minimum that should be accepted for structures carrying railroad tracks. Class B workmanship is what is known as that requiring general reaming, and would probably cost from $1.50 to $3.00 per ton more than Class C, but, in the opinion of many engineers, including the writer, it is worth the difference in cost. Class A workmanship, in addition to general reaming, requires material $\frac{3}{4}$ of an inch thick, or over, to be drilled from the solid. Except for very long spans, or exceedingly heavy structures, the practical effect of this requirement is to limit the thickness of the material to a maximum of 11/16 of an inch. Such a limitation is quite generally considered desirable. Heavy work, necessitating the use of material over 11/16 of an inch thick, under Class A workmanship, will probably cost from $1.50 to $3.00 per ton more than Class B workmanship and $3.00 to $6.00 per ton more than that of Class C. For Highway Bridges and Buildings these requirements for workmanship are considerably reduced. (See Paragraphs 156 and 157.)

The new uniform live load, given in Paragraph 37, which may be substituted for the Cooper concentrated loadings, is presented for the use of engineers who prefer to use uniform loads, rather than wheel loads, in their computations. It will give somewhat greater moments for spans up to about one hundred and fifty feet in length, and slightly smaller moments for spans over four hundred feet in length, which is considered an advantage.

No claim is made for originality in these Specifications. In fact, the time has long since passed in which it has been consistent, or even possible, to introduce much originality in new specifications for structural steel, without greatly sacrificing their value and merit. Writing new specifications has become chiefly a matter of selection, compilation, arrangement and form of expression. In the present case, the writer makes general acknowledgment for assistance to all of the standard specifications which have preceded these.

It is believed that their clearness, wide range of application and number of points covered, will fully compensate for their length.

Special acknowledgment for assistance and advice in the prepa-

ration of this edition is due to Mr. Virgil G. Bogue, under whose direction and approval the work has been done; Mr. J. C. Hallsted, of Robert W. Hunt & Company; Mr. J. Q. Barlow, Chief Engineer of the Western Maryland Railroad; Mr. W. H. Kennedy, Consulting Engineer; Mr. A. B. Hager, Mr. Thomas Earle and Mr. W. A. Aycrigg.

A. W. B.

15 William Street,
New York City.
June, 1906.

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SPECIFICATIONS.

I.

PRELIMINARIES.

Proposals and Letter of Invitation.

1. Bidders shall submit sealed proposals in accordance with all the terms of the letter of invitation or memorandum for bidders and of these specifications. All proposals for a bridge or bridges or structures shall include all bolts and lag screws for fastening ties and guard rails, although the latter may be furnished and placed by the Railroad Company, all anchor bolts and anchors, grillages to be embedded in the masonry, all hand railings and all other metal work required in the completed structures. All claims for royalties on patented devices used in any structure shall be paid by contractor.

The letter of invitation or memorandum for bidders will state whether the work is to be of Class A, B or C. For Class A work, all the requirements of paragraphs 123, 124, 125 and 127 shall be complied with. For Class B work, no drilling from the solid will be required. For Class C work, no drilling from the solid, nor planing of edges, will be required, and rivet holes need not be reamed, except in material over $\frac{5}{8}$ inch thick, used in tension where sub-punching and reaming will be required.

Terms or conditions of the letter of invitation or memorandum for bidders conflicting with these specifications will supersede those herein contained for the work or structures referred to, but no other.

Stress Sheets and General Plans.

2. When not furnished by the Railroad Company, bidders shall submit with each proposal:

(a). Full stress and section sheets, showing maximum and minimum stresses, moments and shears, and the sections proposed, with all data required for checking them.

(b). When specifically required by the letter of invitation or memorandum for bidders, plans, elevations and sections showing the general arrangement, clearances, character of all details and connections and all sizes required from which to make up a detailed estimate. These details will generally be shown to ½-inch scale for trusses and ¼-inch scale for girders, and shall give or indicate the number of rivets to be used in each important connection.

Increase or Decrease of Materials.

3. All proposals and contracts shall be made on the understanding that the Railroad Company may increase or decrease the amount of material in any part of the structure, the price to be paid on the contract being increased or decreased by such amount of material at the unit price named. For this purpose all proposals and contracts made for a lump sum shall contain a unit price for such increase or decrease in the amount of material to be used. Should this unit price be omitted for any cause from a lump sum contract, it is hereby agreed that the lump sum price divided by the weight of metal covered by it shall be the price per pound at which any subsequent increase or decrease in the weight required by the Railroad Company shall be adjusted in the final payment.

Right to Reject Bids.

4. The Railroad Company reserves the right to reject any or all bids.

Working Drawings.

5. As soon as a contract has been awarded, the contractor shall prepare a full set of working drawings in detail, and shall submit two complete sets of blue prints to the Chief Engineer for his approval. After the approval of the drawings, the contractor shall furnish the Chief Engineer with three complete sets of the blue prints for use during construction, and after the completion

of the work the original tracings shall become the property of the Railroad Company, and shall be delivered to the Chief Engineer. The approval of the Chief Engineer shall not relieve the contractor of any responsibility for their accuracy. The contractor alone shall be responsible for the accuracy of drawings and workmanship.

Mill Orders.

6. As soon as the working drawings have been approved by the Chief Engineer, the contractor shall order the material from the mills. Any material ordered before the approval of the drawings shall be at the contractor's own risk. He shall immediately furnish the Chief Engineer with duplicate copies of the mill orders for the use of inspectors.

Changes in Drawings.

7. No change shall be made in any drawing after it has been approved except by consent or direction, in writing, of the Chief Engineer.

Data for Masonry Plans.

8. When not specified by the Railroad Company, the contractor shall, within 15 days from the award of contract, furnish all necessary data for proportioning the masonry work.

II.

GENERAL REQUIREMENTS.

Material.

9. All structures shall be built entirely of structural steel except where otherwise specified. Cast iron or cast steel may be used in the machinery of movable bridges and in special cases for shoes and bearings.

Types of Bridges.

10. Preference will generally be given to the following types of bridges:

For spans up to 20 feet—Rolled beams or longitudinal trough floors.

For spans from 20 feet to 100 feet—Plate girders.

For spans from 100 feet to 175 feet—Riveted trusses.

For spans over 175 feet—Pin connected trusses.

These limits will be modified as required in specific cases.

Double track through bridges will generally have but two trusses or girders to avoid spreading the tracks.

For the purpose of calculating stresses, the length of span shall be taken as the distance center to center of bearing plates for all beams and girders and the distance center to center of end pins for pin connected trusses and riveted trusses or girders with hinged shoes. For floor beams and stringers the distance from center to center of trusses, girders or beams to which they connect, will be taken as the span.

Clearances.

11. All through or half through bridges on tangents, shall have a clear opening not less than that shown on the accompanying clearance diagram. For two or more tracks, the distance from center to center of tracks will be .... On curves the center line of the bridge shall generally be placed midway between and parallel to the chord and tangent to the

curve at center of span, and so as to give equal clearance on each side, and where required to preserve the clearance dimensions shown on diagram, the clear width between trusses shall be increased. In calculating clearance for curvature, the super-elevation of the outer rail shall be that obtained from the following formula, with a car 80 feet long over platforms and 59 feet center to center of the trucks and having a cross section the same as the standard clearance:

$$E = \frac{GV^2}{32.2R}, \text{ with a maximum of 6 inches,}$$

where

E=Elevation of outer rail in feet,
G=Gauge of track in feet,
V=Velocity of train in feet per second, for a speed of 60—3D miles per hour, D being the degree of curvature,
R=Radius of curve in feet.

FLOOR SYSTEM.

Cross Ties.

12. Cross ties will be of long leaf yellow pine, white oak, Oregon fir (Douglas fir), or pine, as may be approved by the Chief Engineer. They shall not be spaced more than 6 inches nor less than 4 inches apart in the clear. They will have a width of 8 inches and a depth depending upon the distance between the centers of supports. For 6 feet 6 inches center to center of the supports they will be 8 inches deep, and for longer distances they will have a depth required by the moment produced by 60,000 pounds on one pair of wheels, taken as distributed over three ties. They will generally be spaced 12 inches center to center and notched one-half inch over supports. In deck plate girders the cross ties shall rest directly on the top flange. Deck truss bridges will preferably be provided with floor beams and stringers, but in special cases the ties may rest directly on the top chords. Ties on deck plate girders shall be 10 or 12 inches deep, when required to give at least 7 inches over the thickest part of the flange. The super-elevation of the outer rail on curves will be obtained by

using beveled ties. The Railroad Company will furnish plans of standard wooden decks, showing also super-elevation of outer rail on curves.

Floor Beams and Stringers.

13. The track stringers will preferably be riveted to the webs of floor beams and shall be spaced 6 feet 6 inches center to center when track is on tangent, with wider spacing when required on curves. When the length of the stringers exceeds 12 times the width of the flange, they shall have their top flanges braced together with a system of diagonal lateral bracing. Stringer lateral bracing will be required in all cases where the alignment is on a curve. Floor beams shall be riveted directly to girders or trusses. In truss bridges they will generally be riveted between the posts above the bottom chord. The design of the connection must be such as to practically avoid eccentricity. End floor beams will be required whenever practicable. The connection angles of stringers to floor beams and floor beams to girders or trusses shall in no case be less than 3½ inches by 3½ inches in size nor less than ½ inch thick.

Solid Floors.

14. Solid floors will generally be designed of rolled I-beams covered with a plate riveted to each beam. Where the section of the plate is necessary to make up a part of the required moment of inertia it shall not be less than ½ inch thick. In cases where a floor of minimum thickness is necessary, trough floors may be used. Troughs shall be built of vertical web plates and horizontal flange plates connected by angles. Solid floors shall be connected to girders or trusses by angles not less in size than 3½ inches by 3½ inches by ½ inch thick. Each I-beam or each web of trough shall be connected to the girder or truss at each end.

15. When solid floors are used with half through plate girders, gussets connecting the floor and girder shall be placed at intervals of not over 12 feet. They shall be as wide at the bottom as the standard clearance dimensions will permit and shall extend to the top flange of the main girder.

Drainage, Gutters, etc.

16. Provision for drainage of solid floor bridges shall be made, subject to the approval of the Chief Engineer. Over streets or roadways and in other places when specially required, drainage gutters and down spouts shall be furnished. The gutters shall be made of No. 20 galvanized iron, and erected in a substantial manner. The down spouts shall be 4 inches in diameter, of cast iron.

PLATE GIRDERS.

Depth of Girders.

17. Plate girders shall generally have a depth of from 1-8 to 1-12 of the span. When limited head room necessitates a less depth than 1-12 of the span, the girder shall be so proportioned that the moment of inertia will be the same as would be required for a girder of the same span with a depth of 1-12 of the span.

Spacing of Girders.

18. Deck plate girders not over 75 feet long will generally be spaced 6 feet 6 inches center to center, except where greater width is required on curves. For girders over 75 feet long, the distance center to center of girders shall not be less than 1-12 of the span.

Flanges and Stiffeners.

19. In girders with flange plates, the angles shall form as large a proportion of the flange area as practicable. When flange plates are not of the same thickness, they shall diminish in thickness outward from the angles. The first flange plate of the top flange shall extend the full length of the girder and all flange plates must be at least one foot longer than their theoretical length. The webs of all plate girders shall have stiffeners over bearing plates and at all points of local concentrated loadings. The projecting leg of the end stiffeners shall be just one size less

than the horizontal leg of the flange angles and there shall be two angles over each end of each bearing.

Splices.

20. Web plates shall be spliced by a plate on each side with sufficient rivets and section to transmit the shear, and in addition shall be spliced by side plates near the flange angles with sufficient rivets and section to make up the loss in the moment of inertia of the girder section due to the web splice. When necessary to splice the flange angles they shall break joints and be spliced by angle splices in pairs on both sides of the flange.

Top Lateral Bracing in Deck Girders.

21. The top lateral bracing of deck girders shall be so designed that the unsupported length of the flange shall not be greater than 12 times its width.

Gusset Plates in Half Through Girders.

22. The cross floor beams will be connected to the main girders in half through girder bridges with gusset plates which shall be as wide as the standard clearance diagram permits. These gusset plates shall be fully spliced to the floor beam webs.

Hinge or Spherical Bearings.

23. Plate girder spans over 75 feet in length shall be provided with pin bearing shoes or cast steel spherical bearings and also with expansion rollers at one end.

Bed Plates and Anchor Bolts.

24. Bed plates under plate girders shall not be less than ¾ of an inch thick with anchor bolts 1¼ inch in diameter extending 12 inches into the masonry. Where two spans rest on an intermediate pier, the masonry plates shall be continuous under both spans. Deck plate girder spans not over 75 feet in length shall

be riveted up complete at the shops, if the shipping facilities permit it, unless otherwise directed by the Chief Engineer.

Rounded Ends.

25. The upper corners of half through plate girders shall be neatly rounded to a radius of about 18 inches, or $\frac{1}{3}$ of the depth of the girder for girders over 54 inches deep. The first flange plate or a plate of the same width will be bent around the curve and continued to the bottom of the girder. In a bridge consisting of two or more spans, only the corners on the extreme ends need be rounded, unless the spans have girders of varying depths, in which case the deeper ones shall have their top flanges neatly curved down to meet the corner of the girder in the next span.

Viaducts and Trestles.

26. Each trestle tower shall in general consist of two adjoining bents, each of which latter will generally consist of two supporting columns. The columns will have a batter transversely not less than 6 vertical to 1 horizontal for single track, and not less than 8 vertical to 1 horizontal for double track. All towers shall be well braced transversely to resist wind pressure, and, if on a curve, centrifugal force; and shall be braced longitudinally to resist the maximum possible stresses due to traction or setting brakes. They shall also have diagonal lateral bracing in horizontal planes in each story and at the feet, and shall have struts between the feet of the columns both in the planes of the bents and of the sides of the towers. The columns shall be anchored to the pedestals or masonry with anchor bolts sufficient to resist double the calculated stresses that may come upon them. The tower spans of high trestles shall not be less than 30 feet center to center of bents and shall alternate with free spans between the towers which may be of economic length. Both the tower spans and free spans will generally consist of plate girders. Foot walks and railings shall be provided when required.

Connections.

27. The tower girders shall be riveted between transverse girders which in turn shall be riveted between the columns. The

free girders shall be riveted to the transverse girders at one end and shall be provided with expansion joints at the other end.

TRUSS BRIDGES.

Main Features.

28. Preference will be given to forms of trusses avoiding all ambiguity in stress and giving the greatest rigidity. Economy in design will be considered wherever possible without a sacrifice of simplicity, rigidity and durability. Adjustable members in any part of the structure shall preferably be avoided. Counter bracing will be preferred to the use of counter members. All parts shall be so designed that they can be inspected, cleaned and painted. Closed sections will not be permitted. Eccentric stresses will not be permitted where avoidable, and when they occur the sections shall be increased to meet these stresses without exceeding the allowed unit stresses. The width center to center of trusses shall generally not be less than one-twelfth of the span and in no case less than one-twentieth of the span.

Riveted Trusses.

29. The upper chords and end posts shall generally be made of two side segments with one cover plate and with tie plates and latticing on the bottom flanges. Gusset plates connecting the various members shall have a thickness proportionate to the amount of stress they have to transfer. The ends of riveted trusses shall be provided with pin bearings and bolsters with provisions for expansion at one end. Masonry plates shall not be less than one inch thick, and where two spans join one another on the same pier they shall extend continuously under the shoes of both spans.

Pin Connected Trusses.

30. Pin connected trusses will generally have inclined end posts, and the bottom chords and suspenders in the two end panels at each end shall be stiff riveted members. All suspenders in through spans shall generally be stiff riveted members.

MOVABLE BRIDGES.

Swing Bridges.

31. Swing bridges shall be calculated for the following conditions:

I. Dead load, bridge swinging.

II. Dead load, bridge closed, ends lifted as per paragraph 34.

III. Live load in any position on one arm, considered as a simple span over two supports.

IV. Live load in any position on one arm only, considered as a continuous span.

V. Live load on both arms, considered as a continuous span.

To obtain the maximum and minimum stresses to be used in proportioning the members, combine condition I with III and V, or II with IV and V.

Turn Tables.

32. Turn tables for swing bridges will be so designed as to avoid ambiguity, and to distribute the loads equally and symmetrically on the masonry.

Machinery.

33. When machinery for operating by power is required, it will be specified, but hand apparatus will be furnished whether or not the bridge is equipped with steam, electric or other power. The time required for opening and closing will be determined by the Chief Engineer, and the contractor will be responsible for the proportions of the machinery to meet this requirement.

The design and quality of material and workmanship used in all operating machinery, wedges, jacks, toggles or cams, latches, rail lifts, signals, indicators, etc., shall be subject to the approval of the Chief Engineer.

All motions shall be controlled from one Cabin, so located as to afford the operator an unobstructed view of the entire bridge and approaches. Provision shall be made in the Cabin for an interlocking signal machine.

Indicators shall be placed in the Cabin to show accurately the

position of all lifts and latches. All bolts in machinery shall be turned and have heads and nuts faced and be provided with check nuts. All bearings shall have oil holes and ducts, and oil cups when required. All shaft bearings will be provided with compression grease cups. These shall be so located as to be as accessible as possible.

Lifts and Latches.

34. When the bridge is closed, a sufficient amount of dead load must be carried by the rest piers to prevent hammering under live load. This will generally be accomplished by end lifts, but may be effected by mechanism controlling the length of the center panel of the top chord. Efficient rail lifts and latches shall be provided, satisfactory to the Chief Engineer. The rails shall have beveled ends and be provided with shoes, guides, bridles, etc. These shall all be furnished by the contractor for the steel superstructure and machinery, and shall include all special rails, but not the straight track rails. The section of special rails shall be that adopted by the Railroad Company as its standard, and shall conform to the Railroad Company's Specifications for steel rails.

Cabin and Signal Lights.

35. An operator's cabin shall be provided, and shall be attractive in design, substantial in construction, and located as directed by the Chief Engineer. Iron ladders or stairs shall be furnished connecting the floor of the bridge with the center pier and with the cabin. The contractor shall furnish and set all signal lights required.

III.

LOADS.

All structures shall be proportioned to carry the following loads:

36. *A dead load,* consisting of the weight of the structure complete, including the floor, tracks, etc. The weight of the rails and fastenings will be assumed at 100 pounds per lineal foot of track, the weight of timber at $4\frac{1}{2}$ pounds per foot B. M., and the weight of ballast at 110 pounds per cubic foot, but the combined weight of the rails, ties and guard rails shall never be taken at less than 400 pounds per lineal foot of track. The dead load will be assumed to be concentrated, $\frac{2}{3}$ on the loaded chord and $\frac{1}{3}$ on the unloaded chord.

37. *A live load,* consisting of two consolidation engines followed by a uniform train load, which, unless otherwise specified, shall be according to the weights and spacing shown on the diagram entitled "Typical Loading" attached hereto; or a concentrated loading of 120,000 pounds on two axles spaced 6 feet center to center. This is the E-50 loading of the Cooper Series.

If heavier or lighter loadings are desired, they will be specified in the letter of invitation and will be designated by the index numbers, as E-40, E-45, E-55, E-60, etc., and they shall be proportional to the E-50 loading, specified above and shown on diagram, with the same wheel base.

Unless otherwise directed by the Chief Engineer, the following uniform live loads per lineal foot of track may be substituted for the typical train loadings above specified:

A live load, per lineal foot of track, of "T" divided by (the cube root of the length of the span in feet plus the sixth root of the length of the span in feet). The values of "T," approximately corresponding to the loadings of the "E" Series, are as follows:

T=40,000	for	E-40	loading.
T=45,000	"	E-45	"
T=50,000	"	E-50	"
T=55,000	"	E-55	"
T=60,000	"	E-60	"

The table hereto attached gives the load per foot of track for "T"=50,000 for spans of 10 feet to 500 feet. For "T" equal to any other value, the load per foot of track will be proportional.

The value of "T," or the index of the loading by this series, is approximately equal to the weight on each driving axle in pounds, or ten (10) times the following load per lineal foot of track.

These loads shall be so placed as to produce the greatest stress in each member. Wherever the live and dead load stresses are of opposite character, only 70 per cent. of the dead load stress shall be considered as effective in counteracting the live load stress.

38. *An allowance for impact or dynamic effect* of live loads, when there is no reversal of stress, equal to the live load multiplied by the maximum stress, divided by the maximum stress plus the minimum stress in the member considered. When a member is subject to reversal of stress, this allowance (to be applied to the live load stress of each kind) shall be equal to that live load multiplied by 1 plus twice (the maximum stress of lesser kind divided by the maximum stress of greater kind). The stresses due to the loads specified in paragraphs 36 and 37, only, shall be used in calculating the above allowances.

Stresses due to momentum, or tractive force of engines and stresses due to centirfugal force, will be increased by an amount to provide for impact or dynamic effect one-half the amount provided for above, and shall be treated as distinct from the impact added to live load stress.

For members in which the maximum stresses are produced by loads on two or more tracks, the above allowances shall be reduced by twenty (20%) per cent.

39. An allowance for wind loads and lateral vibration, as follows:

Dead Load, 150 pounds per lineal foot on the unloaded chord, and 200 pounds per lineal foot on the loaded chord.

Moving Load, 400 pounds per lineal foot on the loaded chord, applied at a distance of six feet above the base of rail.

In calculating the righting moment for wind reactions, the weight of the train will be assumed at 800 pounds per lineal foot. In trestle towers the bracing and columns shall be proportioned to resist the above specified wind loads and in addition a horizontal load of 180 pounds for each vertical foot of bent. In calculating wind stresses in trestle bents carrying double track, the conditions with or without loads on either one or both tracks, and with the maximum train load and with a train load of 800 pounds per lineal foot, shall be considered and the maximum stresses produced by either condition shall be used.

Centrifugal Force.

40. When the structure is located on a curve, a centrifugal force acting 5 feet above the base of rail and treated as live load shall be computed by the following formula for a maximum train on each track moving at a speed of 60—3D miles per hour, D being the degree of curvature. $C=\frac{wv^2}{32.2\ r}$, in which C=centrifugal force, w=weight, v=velocity in feet per second and r= radius of curve.

Traction and Momentum.

41. The stresses produced in the longitudinal bracing of trestle towers or in any members or parts of girders or trusses or any of their attachments or bearings by the greatest tractive force of the engines or by the sudden stopping of trains on any part of the structure must be provided for. In all structures, provision must be made for trains going in either direction and on any track. In determining the reaction and uplift on the base of tower legs, when traction and momentum are considered in combination with wind and centrifugal force, the amount of the former shall be taken at one-half of that above specified.

Thermal Forces.

42. Where designs do not permit of free expansion and contraction due to changes in temperature of 150 degrees, thermal stresses must be provided for.

IV.

WORKING STRESSES.

The following maximum permissible unit stresses shall not be exceeded in any member or part of a structure:

Tension.

43. Axial tension on net section, 16,000 pounds per square inch. For floor beam hangers and suspenders subject to sudden loading, 12,000 pounds per square inch.

Compression.

44. Axial compression on gross section, $16{,}000-800\frac{L}{r}$ pounds per square inch;—

Where L=the length of the member in feet, and r=the least radius of gyration in inches.

The ratio of $\frac{L}{r}$ shall never be greater than $8\frac{1}{2}$ for main members, nor greater than 10 for struts and bracing subject to stress from live or wind loads, but not including struts in viaduct towers, and not greater than 12 for struts and bracing subject to stress from dead load only or for struts in viaduct towers. The least width of posts in pin connected bridges shall be limited to ten (10) inches, for all members subject to stress from live loads.

Combined Stresses.

45. A member subject to transverse stress in addition to the tension or compression due to its position shall be considered as a beam of one panel length supported at the ends for section in center of panel and fixed at the ends for section at the ends of panel. The members will be proportioned to sustain the algebraic sum of the stresses resulting from the direct compression

or tension and the transverse loading, so that the allowed stress per square inch shall not exceed those given above.

NOTE.—For top chords, the stresses per square inch due to weight of member will be deducted from the above unit stresses.

If the length of panel divided by the least radius of gyration of the top chord is less than the length of span divided by the radius of gyration of the top chords, considered as a trussed column, the latter will be used in finding the area of top chord sections.

46. No allowance will be made for wind stress when combined with stress from dead and live load and impact, unless the wind stress exceeds the amount of stress allowed for impact or dynamic effect, in which case the excess of the wind stress over and above that allowed for impact or dynamic effect shall be added to the sum of the other stresses to give the maximum stress to be used in proportioning the section.

Shearing.

47. On pins and rivets, 12,000 pounds per square inch. On webs of girders and beams, $16{,}000 - 100\frac{d}{t}$ pounds per square inch, in which d=the clear distance between flange angles or stiffener angles, and t=the thickness of the web, both in inches.

Stiffeners.

48. All web plates shall be stiffened at the inner edges of end bearing, and at all points of local concentrated loadings. Intermediate stiffeners will be used where required, so that the shearing stress per square inch shall not exceed that given by the formula of the preceding paragraph.

Bearing.

49. On the projected semi-intrados of pin and rivet holes, 24,000 pounds per square inch.

On masonry, 400 pounds per square inch.

Bending.

50. On extreme fiber of rivets and pins, 24,000 pounds per square inch.

51. For rivets driven in the field, except in lateral, sway and longitudinal bracing, the above unit stresses shall be reduced 20 per cent.

For shop driven rivets in lateral, sway and longitudinal bracing, the above unit stresses may be increased 20 per cent.

Timber.

52. *Stress in extreme fibers* under transverse loading, with no allowance for impact or dynamic effect, 1,200 pounds per square inch for yellow pine, white oak and Oregon or Douglas fir, and 1,000 pounds per square inch for pine and other timbers.

Compression, in posts or struts, with no allowance for impact or dynamic effect, $860-110 \frac{L}{d}$ pounds per square inch for yellow pine, white oak and Oregon or Douglas fir, and $750-100 \frac{L}{d}$ pounds per square inch for pine and other timbers.

Where L=the length of the member in feet and d=the least dimension of the member in inches.

Shearing.

Sliding on the grain, 100 pounds per square inch.

Bearing.

Direction of the grain, 1,000 pounds per square inch.

Perpendicular to the grain, 300 pounds per square inch.

Unit Stress for Momentum and Centrifugal Force.

53. Stresses due to momentum, or tractive force of engines, and stresses due to centrifugal force will be increased by an amount to provide for impact, as specified in paragraphs 38, for which purpose the sum of all the stresses, when there is more than one, will be taken as the maximum and the smaller of them that can act separately as the minimum.

Friction.

54. The coefficients of friction will be assumed as follows:

	When acting to increase the stresses.	When acting to decrease the stresses.
For wheels sliding on steel rails..................	0.25	0.15
For plane surfaces of steel or cast iron............	0.30	0.15
For plane surfaces of wood on metal..............	0.50	0.25
For steel rollers between plane surfaces of steel...	0.05	0.001

Bearing on Rollers and Wheels.

55. The pressure per lineal inch on rollers and wheels in pounds shall not exceed, for expansion rollers, 600 D.

For steel wheels of swing bridge turn tables, on steel tracks, 600 D.

Cast iron wheels will not be used.

Where D=diameter of roller or wheel in inches.

Transverse Loading.

56. All beams or girders, rolled or built, shall be proportioned by the least moment of inertia of their net section, and compression flanges shall have the same gross area as tension flanges.

V.

GENERAL DETAILS.

Unsymmetrical Sections.

57. Unsymmetrical sections composed of two rolled or built channels and one plate shall, in chords, be so proportioned that the centers of pins in abutting members shall be in the same line and in the center of gravity of the sections. In web members eccentricity may be made sufficient to counteract the bending stress due to weight of members under maximum load. The material will be concentrated mostly in the channels.

H-Sections.

58. H-shaped sections composed of three channels or four Z-bars, if exceeding ten inches in depth, shall have tie plates at ends holding them truly square.

Tension Members.

59. Tension members in riveted trusses shall be symmetrical and attached to both webs of the chords. Riveted trusses with single web chords will not be used. All parts working together or parts of one member of the truss must be so designed that each part will take its proper proportion of stress.

Floor Beam Connection.

60. In through bridges the floor beams will preferably be above the bottom chord. Vertical posts and stiff suspenders will preferably be composed of four Z-bars or angles, latticed, to which the floor beams will be riveted with rivets in double shear.

Bracing.

61. All lateral, sway and longitudinal bracing shall be made of stiff riveted members. They shall be so connected to the trusses as to give the minimum amount of bending or eccentric stresses.

Lateral Bracing.

62. All bridges, wherever practicable, when over 50 feet in length, shall have both top and bottom lateral bracing.

Top Lateral Struts.

63. Top lateral struts will have a depth equal to the depth of the chord and be securely riveted thereto.

Sway Bracing.

64. All deck bridges and through bridges having a depth of 30 feet, or over, shall have sway bracing at each panel point. Through bridges less than 30 feet in depth shall have knee braces between each intermediate post and top strut. Knee braces or brackets will also be required between each post and sub-strut in through bridges over 30 feet in depth, and at all portals.

Portals.

65. All through bridges shall have portal bracing of approved design between the end posts at each end. For spans of 200 feet and under, each portal will consist of four angles riveted to the end posts and connected by diagonal lacing. The lacing will be flat bars if the depth of portal does not exceed three feet, and angles if of greater depth.

For spans exceeding 200 feet in length, the portals may consist of top and bottom struts connected by cross bracing.

Parallel Deck Spans.

66. Horizontal struts shall be used to connect each panel point of the top chord of parallel deck spans.

Cross Frames.

67. Cross frames shall be used at each end of deck plate girder spans, and intermediate cross frames at intervals of about 20 feet where top and bottom lateral bracing is used, or at intervals of about 12 feet where only top lateral bracing is used.

Stringer Bracing.

68. Track stringers shall be provided with a top lateral system when the span exceeds 12 times the width of the top flange and, in addition, shall have cross frames when the span exceeds 30 feet.

Sections and Connection of Bracing.

69. Braces that take compression, except in deck plate girder spans, shall generally be built of four angles or two channels. Braces that take tension only may consist of one angle, which shall not be less than 4 inches by 3 inches by $\frac{3}{8}$ inch, except for stringer braces, which may be 3 inches by 3 inches by $\frac{3}{8}$ inch. All connections of braces shall have a sufficient number of rivets to develop the full strength of the brace, but in no case will they be connected by less than four rivets for main braces or three rivets for stringer bracing. Braces consisting of a single angle shall have both legs of the angle connected or only one leg will be considered as effective. All intersecting braces shall be riveted together.

Minimum Sections.

70. No metal shall be less than $\frac{3}{8}$ inch thick, except fillers and webs of rolled channels, which latter shall not be less than 5-16 inch thick. No angles shall be used less than $3\frac{1}{2}$x$3\frac{1}{2}$x$\frac{3}{8}$ inches, except for stringer laterals and minor details, which may be 3x 3x$\frac{3}{8}$ inches.

Pins, Pin Plates and Eye Bars.

71. The diameter of the pins shall never be less than $\frac{3}{4}$ of the width of the largest eye bars which they connect, and the axis of all pins must be on the center of gravity of all members connected. The form of heads and method of manufacture of eye bars shall be subject to the approval of the Chief Engineer. Eye bars shall be so arranged or packed as to produce the minimum bending moment in the pins. They shall not be more than one-eighth of an inch in one foot out of parallel with the center line of truss. Pin plates shall be used to give the required bearing surface on the pins, and shall have sufficient rivets to properly

distribute, without eccentricity, the proportion of the stress which they carry. In built tension members the section through pin holes shall be 25 per cent. in excess of the net section of the body of the member. The net section back of the pin hole shall be at least 0.75 of the net section through the pin hole. Where the section at the ends of compression members has been reduced by cutting the flanges, or in any other way, the pin plates shall have enough rivets beyond the reduced portion, and shall have sufficient section to make up the equivalent of the metal cut away.

Shoes, Bed Plates and Rollers.

72. The shoes or bolsters shall be so designed that all loads will act through the end pins, which will be directly over the geometrical center of the bearing, and to properly distribute these loads. Where the necessary height between masonry and center of end pins can be obtained, masonry or bed plates built up of beam sections will be preferred. They shall be securely anchored, with bolts set in cement, which shall not be less than $1\frac{1}{2}$ inches in diameter, nor extend less than 12 inches into the masonry; provision being made for expansion. Where the masonry is of concrete, grillages of steel I-beams will be embedded in the concrete, flush with the surface, to form the bridge seat, for all spans exceeding one hundred feet in length. The contractor for the superstructure shall furnish these grillages as a part of his contract and shall deliver them at the earliest possible date and in advance of the delivery of the steel for the superstructure.

Effective Diameter of Rivets.

73. The effective diameter of the driven rivet will be assumed the same as its diameter before driving, but in making deductions for rivet holes in tension members the diameter of the holes will be assumed $\frac{1}{8}$ inch larger than the undriven rivet.

Pitch of Rivets.

74. The pitch of the rivets shall not exceed 6 inches, nor be less than three diameters of the rivet, where there is only one gauge line, nor exceed nine inches where there are two or more

gauge lines. At the ends of compression members, the pitch shall not exceed four diameters of the rivet for a length equal to twice the depth of the member, and in the flanges of girders and chords carrying floor the pitch shall not exceed 4 inches where there is only one gauge line, nor 8 inches where there are two or more gauge lines. In compression members the pitch in the direction of the stress shall not exceed 16 times the thickness of the outside plate. Transversely to the line of stress it shall not exceed 32 times that thickness, except for the cover plates of trough sections, where it shall not exceed 40 times the thickness of the plate.

Distance from Center of Rivet to Edge of Plate.

75. The distance from center of rivet to edge of plate shall not be less than $1\frac{1}{2}$ inches, except in bars under 3 inches wide. When practicable, it shall be at least two diameters of the rivet. It shall not exceed eight times the thickness of plate.

Grip of Rivets.

76. The grip of the rivets, or the total thickness of all the pieces connected, shall not be more than five times the nominal diameter of the rivet.

Tie Plates and Lacing.

77. The open sides of all members composed of rolled or built channels, or similar sections, and the center of members composed of four angles or Z-bars, without a web plate, shall be stayed by tie plates at the ends and at points of intersection with other members, and by diagonal lacing or lattice bars forming a continuous triangulation between the tie plates.

Length of Tie Plates.

78. The length of tie plates at the ends of members shall be equal to the greatest width of the member. Intermediate tie plates shall have a length at least equal to one-half the greatest width of the member.

Double Lattice.

79. Compression members having a greater clear width than 12 inches between the segments shall be double latticed. All other members may be single laced. Double lattice bars shall form an angle with the axis of the member not less than 45 degrees, shall be riveted at their intersection and have a thickness not less than $\frac{3}{8}$ of an inch nor less than 1-60 of the distance between the rivets connecting them to the members.

Single Lacing.

80. Single lacing bars shall form an angle of not less than 60 degrees with the axis of the member, and have a thickness not less than $\frac{3}{8}$ of an inch nor less than 1-40 of the distance between the rivets connecting them to the members.

Width and Spacing of Bars.

81. No lattice or lacing bar shall be less in width than $2\frac{1}{4}$ inches, nor less than 3 diameters of the rivets. The spacing between connections of the bars shall not exceed six times the least width of the segments connected.

Bolts.

82. All bolts must be of neat length and have a washer under head and nut when they are in contact with wood.

Washers and Nuts.

83. Washers and nuts shall have a uniform bearing. All nuts shall be easily accessible with a wrench, for the purpose of adjustment, and shall be effectively checked after the final adjustment. All nuts must be of hexagonal shape, except those on guard rail bolts and hook bolts in floors, which shall be square.

Drainage.

84. Wherever there is a tendency for water to collect, the spaces must be drained or filled with waterproof material.

Turn Tables of Swing Spans.

85. The drum shall be of sufficient strength to carry all weights which come on it to the adjoining wheels, in case the wheel immediately under the point of support is not bearing. The wheels of the table must be faced to exact size and bevel. The upper and lower tracks must be planed or faced to the true bevel, and must have a face three-fourths of an inch wider than the tread of the wheels. Provisions for lubrication shall be made so as to be easily accessible. The arrangements shall be such that the bearing wheels or the center pins can be readily removed if out of order. The rack, track and center pedestal shall be accurately bolted to the masonry, and in such a manner as will easily permit of adjustment. The design and details for the turn table shall be subject to the approval of the Chief Engineer. The operating machinery shall be the best of its kind and complete in every particular, including small tools and wrenches for all bolts, oil cans, and necessary furnishings. The cabin shall be ceiled inside with matched and beaded ceiling, furnished with necessary doors, windows and hardware, and covered outside with galvanized corrugated iron No. 22. The roof shall be covered with best roofing tin on sheeting and furnished with gutters and down-spouts of No. 22 galvanized iron. All gearing and important castings shall be of steel. Extra or duplicate parts shall be furnished for gearing and other details, a list for which shall be submitted to the Chief Engineer, with the detail or shop plans, for his approval.

Camber.

86. Fixed trusses shall be given a camber by increasing the length of the top chord by one one-thousandth of its length. Swing spans shall be cambered an amount equal to the maximum calculated deflection. Plate girders shall be given a slight camber by proper manipulation in riveting, so that they will not have any sag when erected in place.

Expansion.

87. To provide for expansion and contraction, one end of all spans must be free to move $\frac{1}{8}$ of an inch for each ten feet of length

and shall be provided with expansion rollers or the equivalent when the length of the span exceeds 75 feet. The diameter of the rollers shall not be less than three inches for spans of 75 feet, nor less than six inches for spans of 200 feet, and proportional for other spans.

VI.

QUALITY OF MATERIAL.

Kind of Steel and Chemical Limitation.

88. All steel for bridges and structures shall be made by the open-hearth process and shall not contain more than .05 per cent. sulphur. The phosphorus shall not exceed .08 per cent. in acid steel nor .04 per cent. in basic steel.

Grades of Steel.

89. Excepting for rivets, which shall be made of rivet steel, and excepting for eye bars, pins and rollers, which may be made of medium steel, only one grade of steel will be permitted in the work, and this will be designated as structural steel.

Tensile Strength and Elongation.

90. Wherever the term structural steel is used, it will be understood to mean steel having the following properties:

An ultimate tensile strength of not less than 58,000 pounds nor more than 66,000 pounds per square inch, with an elongation of at least 25 per cent. in eight inches.

Medium steel shall have an ultimate tensile strength of not less than 62,000 pounds nor more than 70,000 pounds per square inch, with an elongation of at least 22 per cent. in eight inches.

Rivet steel shall have an ultimate tensile strength of not less than 48,000 pounds, nor more than 56,000 pounds per square inch, with an elongation of at least 26 per cent. in eight inches.

The Yield Point.

91. For all grades of steel the yield point, as determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine, shall be not less than 55 per cent. of the ultimate tensile strength of the specimen.

The speed of the testing machine shall be so regulated that these determinations can be made accurately and uniformly, and to the satisfaction of the Chief Engineer or his inspectors.

Modifications of Requirements for Elongation.

92. For material less than five-sixteenths inch (5-16 inch) and more than three-fourths inch ($\frac{3}{4}$ inch) in thickness, the following modifications shall be made in the requirements for elongation:

(a). For each increase of one-eighth inch ($\frac{1}{8}$ inch) in thickness above three-fourths inch ($\frac{3}{4}$ inch), a deduction of one per cent. (1 per cent.) shall be made from the specified elongation.

(b). For each decrease of one-sixteenth inch (1-16 inch) in thickness below five-sixteenths inch (5-16 inch) a deduction of two and one-half per cent. ($2\frac{1}{2}$ per cent.) shall be made from the specified elongation.

(c.) For pins made from any grade of steel, the required elongation shall be measured on a gauged length of two inches (2 inches) and may be five per cent. (5 per cent.) less than that specified in paragraph No. 90, as determined on a test specimen, the center of which shall be one inch (1 inch) from the original surface.

Eye Bar Tests.

93. Full-sized tests of eye bars shall show $12\frac{1}{2}$ per cent. elongation in fifteen feet of the body of the eye bar, and the tensile strength shall not be less than 55,000 pounds per square inch. Eye bars shall be required to break in the body, but should an eye bar break in the head, and show twelve and one-half per cent. ($12\frac{1}{2}$ per cent.) elongation in fifteen feet and the tensile strength specified, it shall not be the cause for rejection, provided that not more than one-third ($\frac{1}{3}$) of the total number of eye bars tested break in the head. Eye bar material shall be rolled from ingots from which at least 25 per cent. has been cut off the tops.

Bending and Drifting Tests.

94. All steel shall conform to the following tests:

(d). Rivet steel shall bend cold 180 degrees flat on itself without fracture on the outside of the bent portion.

(e). Structural steel shall bend cold 180 degrees flat on itself without fracture on the outside of the bent portion.

(f). Medium steel shall bend cold 180 degrees around a diameter equal to the thickness of the specimens tested without fracture on the outside of the bent portion.

(g). Hot and quenched bending tests may be made at the discretion of the Chief Engineer or his inspectors, and these, when made, shall conform to the requirements of d, e and f, above.

(h). Punched holes, pitched two diameters from a sheared edge, must stand drifting until the diameter is one-half larger than the original hole, without cracking the metal.

Test Pieces and Methods of Testing.

95. Standard test specimens of eight inch (8 inch) gauged length shall be used to determine the physical properties specified in paragraphs Nos. 90, 91 and 92. The test specimens may be milled on the edges with a parallel section not less than nine inches (9 inches) long, or they may be planed or turned parallel throughout their entire length, and, in all cases where possible, two opposite sides of the test specimens shall be the rolled surface. Rivet rounds and small rolled bars shall be tested of full size as rolled.

Tensile Test Specimens.

96. Two tensile test specimens shall be taken from the finished material of each melt, and from each section or thickness rolled when these vary more than 25 per cent., but in case these develop flaws, or break outside of the middle third of the gauged length, they may be discarded, and other test specimens substituted therefor.

Bending Test Specimens.

97. One test specimen for bending shall be taken from the finished material of each melt as it comes from the rolls, and for material three-fourths inch ($\frac{3}{4}$ inch) and less in thickness, this specimen shall have the natural rolled surface on two opposite sides. The bending test specimen shall be one and one-half inches ($1\frac{1}{2}$ inches) wide, if possible, and for material more than three-fourths inch ($\frac{3}{4}$ inch) thick, the bending test specimen may be

one-half inch ($\frac{1}{2}$ inch) thick. The sheared edges of bending test specimens shall be milled or planed. Rivet rounds and small rolled bars shall be tested of full size as rolled

Condition of Specimens.

98. Material shall be tested for tensile strength in the condition in which it comes from the rolls, without annealing or further treatment.

Chemical Tests.

99. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 88 herein, the contractor shall make analyses of drillings taken from small test ingots, and the results shall be given to the inspector before the material is shipped from the mill. The Chief Engineer may have check analyses made at his option.

Variation in Weight.

100. The variations in cross section or weight of more than $2\frac{1}{2}$ per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

(i). Plates $12\frac{1}{2}$ pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than $2\frac{1}{2}$ per cent. variation above or $2\frac{1}{2}$ per cent. below the theoretical weight. When 100 inches wide and over, 5 per cent. above or 5 per cent. below the theoretical weight.

(k). Plates under $12\frac{1}{2}$ pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, $2\frac{1}{2}$ per cent. above or $2\frac{1}{2}$ per cent. below the theoretical weight; 75 inches wide up to 100 inches wide, 5 per cent. above or 3 per cent. below the theoretical weight; when 100 inches wide and over, 10 per cent. above or 3 per cent. below the theoretical weight.

(l). For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

Plates will be considered up to gauge if measuring not over 1-100 inch less than the ordered gauge.

The weight of one cubic inch of rolled steel is assumed to be 0.2833 pound.

PLATE $\frac{1}{4}$ INCH AND OVER IN THICKNESS.

Width of Plate.

Thickness of plate. Inch.	Up to 75 inches. Per cent.	75 to 100 inches. Per cent.	Over 100 inches. Per cent.
$\frac{1}{4}$	10	14	18
5-16	8	12	16
$\frac{3}{8}$	7	10	13
7-16	6	8	10
$\frac{1}{2}$	5	7	9
9-16	$4\frac{1}{2}$	$6\frac{1}{2}$	$8\frac{1}{2}$
$\frac{5}{8}$	4	6	8
Over $\frac{5}{8}$	$3\frac{1}{2}$	5	$6\frac{1}{2}$

Finish.

101. Finished material must be free from injurious seams, flaws or cracks, and have a workmanlike finish.

Branding.

102. Every finished piece of steel shall be stamped with the melt number, and steel for pins shall have the melt number stamped on the ends. Rivet and lacing steel, and small pieces for pin plates and stiffeners, may be shipped in bundles, securely wired together, with the melt number on a metal tag attached.

CAST STEEL.

Process of Manufacture.

103. Steel for castings may be made by the open-hearth, or crucible, process. Castings shall be annealed, unless otherwise specified.

Chemical Properties.

104. Castings shall not contain over 0.05 per cent. of phosphorus, nor over 0.05 per cent. of sulphur.

Physical Properties.

105. The minimum physical qualities required shall be as follows:

Tensile strength, pounds per square inch........	70,000
Yield point, pounds per square inch...........	31,500
Elongation, per cent. in two inches............	18

Drop Test.

106. A test to destruction may be substituted for the tensile test in the case of small or unimportant castings, by selecting three castings from a lot. This test shall show the material to be ductile and free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from the same melt or blow, annealed in the same furnace charge.

Percussive Test.

107. Large castings are to be suspended and hammered all over. No cracks, flaws, defects nor weakness shall appear after such treatment.

Bending Test.

108. A specimen one inch by one-half inch (1 inch by ½ inch) shall bend cold around a diameter of one inch (1 inch) without fracture on outside of bent portion, through an angle of 90 degrees.

Test Specimen for Tensile Test.

109. The standard turned test specimen, one-half inch (½ inch) diameter and two inch (2 inch) gauged length, shall be used to determine the physical properties specified in paragraph No. 105.

Number and Location of Tensile Specimens.

110. The number of standard test specimens shall depend upon the character and importance of the castings. A test piece shall be cut cold from a coupon to be molded and cast on some portion of one or more castings from each melt or blow or from the sink-heads (in case heads of sufficient size are used). The coupon or sink-head must receive the same treatment as the casting or castings before the specimen is cut out, and before the coupon or sink-head is removed from the casting.

Test Specimen for Bending.

111. One specimen for bending test one inch by one-half inch (1 inch by ½ inch) shall be cut cold from the coupon or sink-head of the casting or castings, as specified in paragraph No. 110. The bending test may be made by pressure, or by blows.

Yield Point.

112. The yield point specified in paragraph 105 shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

Sample for Chemical Analysis.

113. Turnings from the tensile specimen, drillings from the bending specimen, or drillings from the small test ingot, if preferred by the Chief Engineer, shall be used to determine whether or not the steel is within the limits in phosphorus and sulphur specified in paragraph No. 104. The contractor shall make these analyses and hand the results to the inspector before the castings are accepted or shipped, but the Chief Engineer may have check analyses made at his option.

Finish.

114. Castings shall be true to pattern, free from blemishes, flaws or shrinkage cracks. Bearing surfaces shall be solid, and no porosity shall be allowed in positions where the resistance and value of the casting for the purpose intended will be seriously affected thereby.

Cast Iron.

115. Cast iron shall be of the best quality, tough gray iron. Bars one inch square in section and five feet (5 feet) long, when supported by knife edges four feet six inches (4 feet 6 inches) apart, center to center, must carry a load of 500 pounds placed midway between supports without rupture. Castings shall be clean and free from defects of every kind, boldly filleted at angles and the arrises shall be sharp and perfect.

Timber.

116. All timber must be of the best quality of long leaf yellow pine, white oak, Oregon fir (Douglas fir) or pine, sawed true to size and out of wind, with ends cut square and be full cornered. Yellow pine in all square sizes shall show two-thirds heart on two sides, and not less than one-half heart on two other sides, and other sizes shall show two-thirds heart on face and show heart two-thirds of length on edges, excepting when the width exceeds the thickness by three inches, or over, then it shall show heart on the edge for one-half the length. All timber must be free from wind shakes, loose or rotten knots, worm holes, or other defects that will impair its strength or durability. Oregon or Douglas fir and pine shall not have more than one inch of sap on corners.

Creosoted Timber.

117. When creosoted timber is specified or required on the work, it shall contain 20 pounds of creosote oil to the cubic foot. The process of creosoting, including the period of time it shall remain in vacuum and under pressure, and the amount of vacuum and the pressure, shall be subject to the approval of the Chief Engineer.

PAINT AND OIL.

Linseed Oil.

118. Linseed oil shall be pure, aged six months and double kettle boiled. It shall be free from all adulterations, and not con-

tain any fish oil nor mineral oil, and no drier, except turpentine. No more than 10 per cent. of turpentine will be allowed either in linseed oil or in paint.

Iron Oxide.

119. The iron oxide shall contain not less than 90 per cent. of sesquioxide of iron and be practically free from sulphur and moisture. It shall be finely ground, and, if lumpy, shall be roasted, to drive off the water.

Paint.

120. Paint will consist of pure, double kettle boiled linseed oil, iron oxide and pure turpentine, mixed in the proportions of 8 pounds of red oxide of iron to a gallon of oil, and not over one gallon of turpentine to each 10 or 12 gallons of oil. It shall be well mixed.

Inspection.

121. Every facility for inspection of material and mixing shall be furnished by the manufacturer, and the Chief Engineer, or his inspector, shall be allowed full access to all parts of the establishment in which, and at all times when, any portion of the work is being executed.

VII.

WORKMANSHIP.

General.

122. All workmanship shall be first-class in every particular, and all methods used during manufacture shall be satisfactory to the Chief Engineer.

All material shall be perfectly straight before any work is done upon it in the shop.

Drilling.

123. Rivet holes in all material $\frac{3}{4}$ inch thick and over shall be drilled from the solid. Where all the parts are $\frac{3}{4}$ inch thick or over, they shall be held together while being drilled by bolts about three feet apart in holes drilled for the purpose. These holes shall be drilled $\frac{1}{8}$ inch smaller than the nominal size of the rivets to be used, and reamed to size after other holes are drilled, and the work shall in all cases be taken apart and any shavings between pieces carefully removed before the final assembling for riveting. All other material except lateral, longitudinal and sway bracing shall be sub-punched and reamed. When a member is made up of some material $\frac{3}{4}$ inch thick or over and some less than $\frac{3}{4}$ inch thick, the parts that are $\frac{3}{4}$ inch thick or over shall be drilled 1-16 inch smaller than the nominal size of the rivet, and those that are less than $\frac{3}{4}$ inch thick shall be sub-punched $\frac{1}{8}$ inch smaller than the nominal size of the rivet. They shall then be bolted together and reamed as in sub-punched and reamed work.

Punching and Reaming.

124. In sub-punched and reamed work the holes shall first be punched $\frac{1}{8}$ inch smaller and then reamed 1-16 inch larger than the nominal size of the rivets. The sharp edges must be removed from all reamed or drilled holes.

Reamed work shall be thoroughly bolted together, so that no

shavings will be forced in between the assembled parts during the reaming.

Accuracy.

125. All drilling or reaming shall be so accurately done that after assembling, the rivets can be entered without further reaming or injurious drifting.

All holes for field connections, except those in lateral, longitudinal and sway bracing, shall be accurately drilled to a metal template, or, when required by the Chief Engineer, reamed while the connecting parts are temporarily put together, and all parts properly match-marked.

All turn tables and turn tables of swing bridges and other complicated or movable structures shall be completely assembled at the shops and match-marked before shipment.

Punching of Laterals, etc.

126. Lateral, longitudinal and sway bracing may be punched with holes 1-16 of an inch larger than the size of the rivets; this shall be so accurately done that the holes will come truly opposite; if any hole must be enlarged to admit the rivet, it shall be reamed, as no drifting that will distort the metal will be allowed. Holes in this bracing which, in the structure, are continuous with drilled or reamed holes, shall be reamed. The diameter of the punch shall not be more than 1-16 inch larger than the nominal size of the rivet, and the diameter of the die shall not be more than 1-16 inch larger than the diameter of the punch.

Planing Edges.

127. All sheared edges of material ½ inch or over in thickness shall be planed off to a depth of 3-16 inch, or as much more as may be necessary, to remove the sheared surface of the metal.

Rivets.

128. Rivets shall completely fill the holes, have full heads concentric with the rivet of a height not less than 0.6 diameter of the rivet, and in full contact with the surface, or be counter-sunk

when so required, and machine-driven when practicable. Rivets shall not be used in direct tension. Built members, when finished, must be true and free from twists, kinks, buckles, or open joints between the component pieces.

Field Rivets and Bolts.

129. Field riveting shall preferably be done by pneumatic riveters of approved make. No hand-driven rivets over $\frac{7}{8}$-inch diameter will be allowed.

When members are connected by bolts which transmit shearing strains, the holes must be reamed parallel and the bolts turned to a driving fit.

Finished Surfaces, Joints and Fillets.

130. All abutting surfaces of compression members, except flanges of plate girders, where the joints are fully spliced, shall be faced true and square, so that they will be in contact throughout when in position in the structure. Tower footings and bed plates must be planed true on all sliding surfaces.

All ends of stringers, where they are riveted between floor beams, shall be faced, and shall be of exact lengths. The connection angles shall be true with the faced ends, or, if dressed, shall not lose more than 1-16 inch in thickness.

All bearing surfaces of base plates, masonry plates and vertical webs of pedestals shall be planed; also all sliding surfaces of shoe plates.

Web plates of all girders shall be so arranged as not to project beyond the face of the flange angles, nor at the top and ends be more than one-eighth inch below the face of the angles at any point.

All members shall be assembled at the shops and match-marked when required by the Chief Engineer. Turn tables and other movable and complicated structures, hip roofs, etc., shall, without exception, be completely assembled at the shops, in operating order for movable structures, and carefully fitted and match-marked.

Sharp unfilleted angles will not be allowed, and wherever a

plate or shape has been cut into, the cut must be finished with sharp cutting tools, or with chisel or file, so that no signs of ragged or bent edges remain.

Stiffener Angles.

131. All stiffener angles shall fit tight against the flange angles. All fillers and splice-plates on the web of girders and riveted members must fit sufficiently tight to the flange angles to exclude water after being painted.

Pins, Pilots and Rollers.

132. Pins shall be turned true to size and straight. They shall be turned down to a smaller diameter at the ends, and shall be supplied with one pilot nut for every 20 pins or less. There shall be a washer for adjustment under at least one nut, unless recessed nuts are used.

Rollers must be finished perfectly round, and roller beds planed.

Pin Holes.

133. All pin holes shall be accurately bored at right angles to the axis of the members, and in pieces not adjustable for length no variation of more than one-sixty-fourth of an inch in twenty feet will be allowed in the length between centers of pin holes; the diameter of the pin holes shall not exceed that of the pins by more than one-thirty-second inch, nor by more than one-fiftieth inch for pins under three and one-half inches diameter.

Eye Bars.

134. Eye bars must be straight before boring; the holes must be in the center of the heads and on center line of the bars. All bars belonging to the same panel, when placed in a pile, must allow the pin at each end to pass through at the same time without forcing. No welds will be allowed in the body of the bars, nor in the heads.

Eyes of laterals, stirrups, sway rods and counters must be bored.

Upset Ends.

135. All bars with screw ends shall be upset at the ends, so that the area at the root of the thread shall be at least 10 per cent. larger than the body of the bar. Open turn buckles will be preferred to closed sleeve nuts, and shall always be used for counters.

Screw Threads.

136. All screw threads shall be United States standards, except at the ends of pins.

Annealing.

137. In all cases where a steel piece in which the full strength is required has been partially heated, the whole piece must be subsequently annealed. All bends in steel must be made cold, or, if the radius of curvature is so small as to require heating, the whole piece must be subsequently annealed.

VIII.

PAINTING.

138. All scale, rust and dirt shall be removed before applying oil or paint to structural steel, and no paint nor oil shall be applied to damp surfaces. All surfaces in contact with each other shall receive one coat of paint before assembling, and all other surfaces one coat of paint before leaving the shop. All finished surfaces shall be coated with white lead and tallow.

After erection the entire work shall receive two good coats of paint, the color of the second coat to be approved by the Chief Engineer. The paint must be carefully and evenly laid, and well worked into the joints and crevices.

All painting shall be done by competent and experienced workmen, satisfactory to the Chief Engineer or his inspector.

IX.

INSPECTION.

Full Size Tests.

139. Any full-sized member tested to destruction shall be paid for at cost, less its scrap value, if it proves satisfactory. If it does not stand the specified test, it will be considered rejected material, and be solely at the cost of the contractor.

Testing Machines.

140. The contractor shall furnish testing machines of the proper capacity, and shall prepare and test, without charge, such specimens as may be required by the Chief Engineer or Inspector.

Access to Works.

141. Every facility for inspection of material and workmanship shall be furnished by the contractor, and the Engineer and Inspector shall be allowed full access to all parts of the establishment in which, and at all times when, any portion of the material is being made or work is being executed.

Notice.

142. Timely notice will be given to the Engineer by the contractor of when he is ready for the Inspectors, and the Inspectors will test and inspect the material at as early a period as the nature of the work permits.

All material must be inspected, weighed and stamped by the Inspector before shipment. Each member or set of duplicate members shall be weighed and invoiced separately, and the weight of all tools and erection material shall be kept separate.

All pins, nuts, bolts, rivets or other small details shall be boxed or crated, so that they can be easily handled in unloading, and to insure against loss or damage.

Work for export must be so designed that no member shall exceed, in length or weight, the limits fixed by the conditions for economically handling and shipping; and the contractor shall obtain from the purchaser, or his agent or engineer, the maximum lengths and weights permissible. Screw ends and other parts liable to injury shall be properly protected by wrapping, or other efficient means, to the satisfaction of the purchaser, or his agent or engineer.

Defective Materials.

143. The acceptance of any material or manufactured member by the Inspector shall not prevent its subsequent rejection if found defective after delivery, and such materials or members shall be replaced by the contractor without extra charge.

Interpretation of Drawings and Specifications.

144. The decision of the Chief Engineer shall control as to the interpretation of the drawings and specifications during the execution of the work thereunder.

X.

ERECTION.

Extent of the Work.

145. Unless otherwise specifically agreed upon, the contractor shall furnish, at his own expense, all staging, piling, false-work, material and tools, and shall erect the structure complete, ready for the ties, if the ties rest on the steel work, or ready for the rails or ballast, if the structure is to have a solid floor. In cases of renewal, he shall remove the old structure without unnecessarily damaging any of its parts, and carefully mark and inventory the same, noting all defects, to facilitate re-erection. He shall load the old material on cars, or carefully pile it near the work, as the Chief Engineer may direct.

Conditions.

146. The contractor shall notify the Chief Engineer when he is ready to commence operations, and shall not begin until the Chief Engineer has given him written authority to do so, and approved the proposed method. All operations shall be so conducted as not to impede or interrupt the operations of the road or of other contractors, nor close any thoroughfare or waterway, nor conflict with any law, regulation or ordinance of any properly constituted authority. The contractor shall obtain all necessary permits and comply with their requirements.

Watchmen, Risks, etc.

147. The contractor shall furnish, at his own expense, all watchmen, flagmen, and other safeguards necessary for the safe movement of trains, as directed by the Chief Engineer. Flagmen must be familiar with the rules and regulations of the Railroad Company, and, if the contractor desires, they will be furnished to him by the Railroad Company at cost. The contractor shall as-

sume all risks of accidents to men or material prior to the acceptance of the finished structure by the Railroad Company.

Maintaining and Cutting Track.

148. The contractor shall support the Railroad Company's tracks when required, and this work shall be executed in exact accord with all directions of, and with plans that shall have been approved by, the Chief Engineer. Any cutting or changing of tracks that may be required will be done by the Railroad Company.

Details of Erection.

149. The contractor shall erect the structure to the exact lines and grades shown on plans, and as laid out by the Chief Engineer. Material shall be handled carefully, to avoid injury, and, when injured, it may be rejected. It shall be piled on skids, to keep it off the ground and clean. Field riveting shall be done in accordance with paragraphs 128 and 129. At the completion of the work, and before its acceptance by the Railroad Company, the contractor shall remove all timber, false-work and rubbish, and leave the site unobstructed and clean.

When Railroad Company Erects.

150. In case the Railroad Company is to erect the work by the terms of the contract, the manufactured material shall be consigned to the Chief Engineer, as will be directed. Any extra cost incurred by the Railroad Company, on account of defective work, will be charged to the contractor, and he shall bear such cost.

XI.

HIGHWAY BRIDGES AND BUILDINGS.

General.

151. Highway bridges, buildings and roofs shall conform to all the foregoing requirements of these specifications wherever applicable, except in the following particulars:

The floor shall consist of oak plank laid on steel stringers, or of a pavement similar to that in the connecting streets or roadways, of macadam, granite blocks, or asphalt, with cement sidewalk pavement, supported on concrete floor arches or slabs.

Loads.

152. Highway bridges shall be proportioned to carry a live load of 115 pounds per square foot of both roadway and sidewalk reduced by one pound for each five feet of length of span down to a minimum of 60 pounds per square foot, or a concentrated load of ten tons on two axles six feet center to center and five feet gauge. When car tracks are to be provided for, a 30-ton electric car, 30 feet long over all, with a wheel base of 19 feet, on two trucks 15 feet center to center, shall be used. A wind load of 150 pounds per lineal foot on the unloaded chord and 300 pounds per lineal foot on the loaded chord shall be provided for. One-half of the latter shall be treated as a live load.

Floors of buildings shall be proportioned to carry live loads, as follows:

Offices	75 lbs. per sq. ft.
Public rooms, stations, etc.	125 " " " "
Warehouses and station platforms, from 150 to	300 " " " "
Flat roofs	75 " " " "
One-quarter pitch roofs	50 " " " "

The latter will be assumed to include the effect of wind on the roof trusses. All buildings shall be proportioned to resist a wind pressure of 30 pounds per square foot of exposed surface.

Working Unit Stresses and Allowance for Impact.

153. The maximum permissible unit stresses in highway bridges, buildings and roofs shall be the same as those given for railroad bridges in paragraphs 43 to 56, inclusive, except those of paragraph 52, which may be increased twenty-five (25) per cent.

For highway bridges the allowance for impact or dynamic effect shall be one-half of that specified in paragraph 38.

For buildings and roofs no allowance will be made for impact or dynamic effect.

Sway Bracing.

154. Through highway bridges more than 25 feet in depth shall generally have sway bracing and sub-struts.

Minimum Sections.

155. In highway bridges no metal shall be used less than 5-16 of an inch thick, except the webs of rolled channels, which may be $\frac{1}{4}$ of an inch thick. No angles less than 3 inches x $2\frac{1}{2}$ inches x 5-16 inch shall be used, except for lateral and sway bracing, where they may be $2\frac{1}{2}$ inches x 2 inches x $\frac{1}{4}$ inch. No lateral or sway rod shall be less in size than $\frac{7}{8}$-inch diameter, or $\frac{3}{4}$ inch square. No lacing or lattice bars shall be used less than $1\frac{1}{2}$ inches x $\frac{1}{4}$ inch, nor less in width than three times the diameter of the rivets. The ratio of thickness to the distance between rivets may be twenty-five (25) per cent. greater than specified in paragraphs 79 and 80. In roof trusses no metal will be permitted under $\frac{1}{4}$ inch thick, no angles less than $1\frac{3}{4}$ x $1\frac{3}{4}$ x $\frac{1}{4}$ inches, and no rods less than $\frac{3}{4}$ inch in diameter. The smallest rivets in highway bridge work will generally be $\frac{5}{8}$-inch diameter, and in roof trusses $\frac{1}{2}$-inch diameter. The least width of posts in pin connected bridges shall be limited to six (6) inches, for all members subject to stress from live loads.

Punching and Reaming.

156. Rivet holes in material for highway bridges, if not over $\frac{5}{8}$ of an inch thick, may be punched without reaming, as specified in paragraph 126. Rivet holes in material $\frac{5}{8}$ of an inch thick and over shall be punched and reamed according to paragraph 124. Rivet holes in all material for buildings and roofs may be punched without reaming, the work being done as required by paragraph 126

Planing.

157. The edges of sheared plates for highway bridges and buildings need not be planed, but shall be sheared true and even. The ends of stringers, beams and girders for highway bridges and buildings need not be faced, but the connection angles shall be square and set to exact length.

Building Laws.

158. When buildings are erected within the jurisdiction of established building laws or codes they shall conform to the requirements of the same in every particular, and such laws or codes will supersede these specifications when and wherever they are in conflict, but not otherwise.

The latter will be assumed to incl...
roof trusses. All h...

f... ...agraph 38.
... no allowance will be made for impact
or ...mic effect.

Sway Bracing.

154. Through highway bridges more than 25 feet in depth shall generally have sway bracing and sub-struts.

Minimum Sections.

155. In highway bridges no metal shall be used less than 5-16 of an inch thick, except the webs of rolled channels, which may be ¼ of an inch thick. No angles less than 3 inches x 2½ inches x 5-16 inch shall be used, except for lateral and sway bracing, where they may be 2½ inches x 2 inches x ¼ inch. No lateral or sway rod shall be less in size than ⅝-inch diameter, or ¾ inch square. No lacing or lattice bars shall be used less than 1½ inches x ¼ inch, nor less in width than three times the diameter of the rivets. The ratio of thickness to the distance between rivets may be twenty-five (25) per cent. greater than specified in paragraphs 79 and 80. In roof trusses no metal will be permitted under ¼ inch thick, no angles less than 1¾ x 1¾ x ¼ inches, and no rods less than ¾ inch in diameter. The smallest rivets in highway bridge work will generally be ⅝-inch diameter, and in roof trusses ½-inch diameter. The least width of posts in pin connected bridges shall be limited to six (6) inches, for all members subject to stress from live loads.

Punching and Reaming.

156. Rivet holes in material for highway bridges, if under $\frac{5}{8}$ of an inch thick, may be punched without reaming, as specified in paragraph 126. Rivet holes in material $\frac{5}{8}$ of an inch thick and over shall be punched and reamed according to paragraph 124. Rivet holes in all material for buildings and roofs may be punched without reaming, the work being done as required by paragraph 126.

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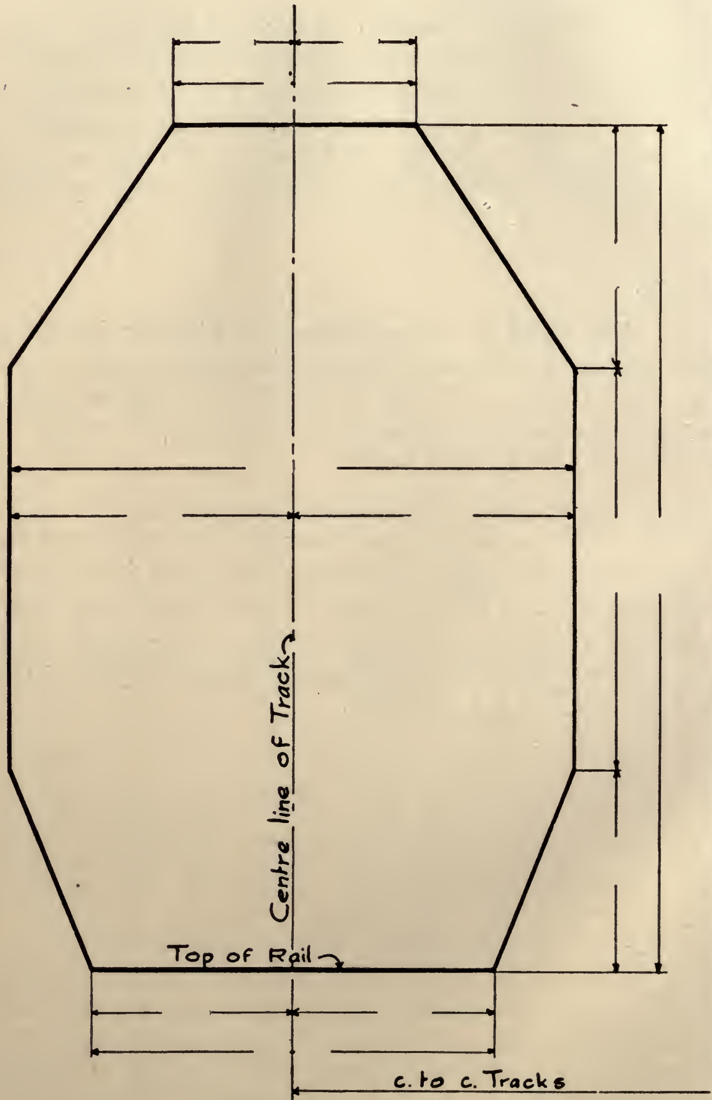
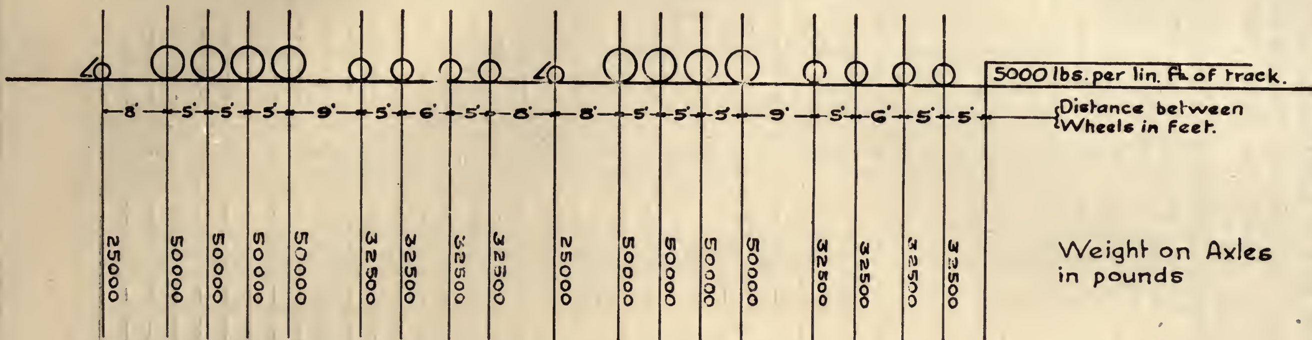


Standard Clearance Diagram.



Typical Loading

2-177½ Ton Consolidation Engines
followed by 5000 lbs. per lin. ft. of track.

MOMENT TABLE

for Two 177.5 Ton Typical Consolidation Engines and Tenders,
Followed by 5000 pounds per lineal foot
For one rail.
Weights in thousands of pounds. Moments in thousands of ft. pounds.

Number of Wheel.	Distance from 1st Driver Feet.	Weight on Wheel.	Distance between Wheels Feet.	Weight between 1st wheel and axis.	Moment of weights between 1st wheel and axis.
1	8	12.50	8	12.50	
2	0	25.00	5	37.50	100
3	5	25.00	5	62.50	288
4	10	25.00	5	87.50	600
5	15	25.00	9	112.50	1038
6	24	16.25	5	128.75	2050
7	29	16.25	6	145.00	2694
8	35	16.25	5	161.25	3564
9	40	16.25	8	177.50	4370
10	48	12.50	8	190.00	5790
11	56	25.00	5	215.00	7310
12	61	25.00	5	240.00	8385
13	66	25.00	5	265.00	9585
14	71	25.00	9	290.00	10910
15	80	16.25	5	306.25	13520
16	85	16.25	6	322.50	15051
17	91	16.25	5	338.75	16986
18	96	16.25	10	355.00	18680
19	106	25.00	10	380.00	22230
20	116	25.00	10	405.00	26030
21	126	25.00	10	430.00	30080
22	136	25.00	10	455.00	34380
23	146	25.00	10	480.00	38930
24	156	25.00	10	505.00	43730
25	166	25.00	10	530.00	48780
26	176	25.00	10	555.00	54080
27	186	25.00	10	580.00	59630
28	196	25.00	10	605.00	65430
29	206	25.00	10	630.00	71480
30	216	25.00	10	655.00	77780
31	226	25.00	10	680.00	84330
32	236	25.00	10	705.00	91130
33	246	25.00	10	730.00	98180
34	256	25.00	10	755.00	105480
35	266	25.00	10	780.00	113030
36	276	25.00	10	805.00	120830
37	286	25.00	10	830.00	128880
38	296	25.00	10	855.00	137180
39	306	25.00	10	880.00	145730
40	316	25.00	10	905.00	154530

Maximum Moments, End Shears
and
Floor Beam Reactions.
E 50 Loading.

Moments in thousands of foot lbs. Shears in thousands of lbs.

Span in Feet.	Maximum Moment	End Shear.	Fl Bm. Reaction.	Span in Feet.	Maximum Moment.	End Shear.	Fl. Bm. Reaction
10	70.3	37.5	50.0	46	1036.9	103.5	150.9
11	82.1	40.9	54.6	48	1110.0	106.0	156.0
12	100.0	43.8	58.3	50	1182.2	108.9	161.0
13	118.8	46.1	61.6	52	1268.8	111.6	166.6
14	137.5	48.3	65.2	54	1351.3	114.0	172.4
15	156.3	50.0	68.3	56	1440.0	116.3	178.3
16	175.0	53.2	71.1	58	1528.8	119.3	185.1
17	193.8	55.9	73.5	60	1624.4	122.0	191.6
18	212.5	58.4	75.8	62	1720.5	125.1	197.6
19	233.3	60.5	78.6	64	1819.4	128.3	203.6
20	257.8	62.5	81.9	66	1924.4	131.3	209.7
21	282.5	64.3	85.0	68	2029.4	134.8	215.6
22	307.1	65.9	87.7	70	2134.4	138.1	221.3
23	331.8	67.4	90.2	72	2240.0	141.7	
24	356.5	69.3	92.5	74	2348.8	145.4	
25	381.3	71.0	94.6	76	2463.8	148.8	
26	406.0	72.6	97.1	78	2580.5	152.1	Trestles
27	430.8	74.1	100.1	80	2700.5	155.3	30' & 60'
28	456.9	75.5	102.9	82	2820.6	158.6	Spans
29	484.9	76.9	105.4	84	2945.6	161.9	149.3
30	513.1	78.8	107.8	86	3074.4	165.1	
31	541.1	80.5	110.6	88	3205.0	168.4	40' & 60'
32	569.3	82.2	113.8	90	3338.1	171.6	Spans
33	597.3	83.7	116.7	92	3470.0	174.8	164.3
34	625.4	85.1	119.4	94	3607.0	177.9	
35	653.8	86.5	122.0	96	3742.5	181.0	
36	685.6	88.2	124.4	98	3883.1	184.4	
37	717.8	89.9	126.8	100	4025.0	187.5	
38	750.0	91.4	129.7	105	4421.9	195.1	
39	783.4	92.9	132.3	110	4858.8	202.5	
40	819.4	94.3	135.0	115	5306.3	209.9	
42	891.9	97.6	140.0	120	5767.5	217.1	
44	964.4	100.7	145.6	125	6245.6	224.2	

Uniform Live Loads in Pounds
for T = 50,000.
Other loadings proportional.

Span in Feet. S	$\sqrt[3]{S}$	$\sqrt[6]{S}$	$\sqrt[3]{S}+\sqrt[6]{S}$	Uniform Live Load per foot of Track. $\frac{50,000}{\sqrt[3]{S}+\sqrt[6]{S}}$
10	2.1544	1.4678	3.6222	13 804
15	2.4662	1.5704	4.0366	12 387
20	2.7144	1.6475	4.3619	11 463
25	2.9240	1.7100	4.6340	10 790
30	3.1072	1.7627	4.8699	10 267
35	3.2711	1.8086	5.0797	9 843
40	3.4200	1.8493	5.2693	9 489
45	3.5569	1.8860	5.4429	9 186
50	3.6840	1.9194	5.6034	8 923
55	3.8030	1.9501	5.7531	8 691
60	3.9149	1.9786	5.8935	8 484
65	4.0207	2.0052	6.0259	8 298
70	4.1213	2.0301	6.1514	8 128
75	4.2172	2.0536	6.2710	7 973
80	4.3089	2.0758	6.3847	7 831
85	4.3968	2.0969	6.4937	7 700
90	4.4814	2.1169	6.5983	7 578
95	4.5629	2.1361	6.6990	7464
100	4.6416	2.1544	6.7960	7357
110	4.7914	2.1889	6.9803	7 163
120	4.9324	2.2209	7.1533	6990
130	5.0658	2.2507	7.3165	6834
140	5.1925	2.2787	7.4712	6692
150	5.3133	2.3051	7.6184	6563
160	5.4288	2.3300	7.7688	6436
170	5.5397	2.3536	7.8933	6334
180	5.6462	2.3762	8.0224	6233
190	5.7489	2.3977	8.1466	6138
200	5.8480	2.4183	8.2663	6049
225	6.0822	2.4662	8.5484	5 849
250	6.2996	2.5099	8.8095	5676
275	6.5030	2.5501	9.0531	5523
300	6.6943	2.5873	9.2816	5 387
325	6.8753	2.6221	9.4974	5 265
350	7.0473	2.6547	9.7020	5 154
400	7.3700	2.7150	10.0850	4960
500	7.9400	2.8170	10.7570	4650

CENTRIFUGAL FORCE
ON RAILROAD STRUCTURES

Degree of Curvature=D	1	2	3	4	5	6	7	8	9	10	11	12
Radius of Curve = r	5729.65	2864.93	1910.08	1432.69	1146.28	955.37	819.02	716.78	637.28	573.69	521.67	478.34
Speed in miles per hour	57	54	51	48	45	42	39	36	33	30	27	24
Velocity in feet per second	83.6	79.2	74.8	70.4	66.0	61.6	57.2	52.8	48.4	44.0	39.6	35.2
V^2	6989	6273	5595	4956	4356	3795	3272	2788	2343	1936	1568	1239
$32.2r$	184480	92240	61500	46130	36910	30760	26370	23080	20520	18470	16800	15400
$V^2 \div 32.2r = h$	.0379	.0680	.0910	.1074	.1180	.1234	.1241	.1208	.1142	.1048	.0933	.0805

$C = \frac{WV^2}{32.2r}$ C = Centrifugal force W = Weights on Structure

Speed in miles per hour = $60 - 3D$

$C = Wh$

Moment due to Centrifugal Force = Mh

End Shear " " " = Sh

Where M = Moment due to live load

And S = End Shear " " "

Coefficients of Impact when there is no reversal of stress

min / max.	Percent of Live Load.	min. / max.	Percent of Live Load	min. / max	Percent of Live Load	min. / max.	Percent of Live Load.
.00	1.0000						
.01	.9901	.26	.7937	.51	.6623	.76	.5682
.02	.9804	.27	.7874	.52	.6579	.77	.5650
.03	.9709	.28	.7813	.53	.6536	.78	.5618
.04	.9615	.29	.7752	54	.6494	.79	.5587
.05	.9524	.30	.7692	.55	.6452	.80	.5556
.06	.9434	.31	.7634	56	.6410	.81	.5525
.07	.9346	.32	.7576	.57	.6369	.82	.5495
.08	.9259	.33	.7519	.58	.6329	.83	.5464
.09	.9174	.34	.7463	.59	.6289	.84	.5435
.10	.9091	.35	.7407	.60	.6250	.85	.5405
.11	.9009	.36	.7353	.61	.6211	.86	.5376
.12	.8929	.37	.7299	.62	.6173	.87	.5348
.13	.8850	.38	.7246	.63	.6135	.88	.5319
.14	.8772	.39	7194	.64	.6098	.89	.5291
.15	.8696	.40	.7143	.65	.6061	.90	.5263
.16	.8621	.41	.7092	.66	.6024	.91	.5236
.17	.8547	.42	.7042	.67	.5988	.92	.5208
.18	.8475	.43	.6993	.68	.5952	.93	.5181
.19	.8403	.44	.6944	.69	.5917	.94	.5155
.20	.8333	.45	.6897	.70	.5882	.95	.5128
.21	.8264	.46	.6849	.71	.5848	.96	.5102
.22	.8197	.47	.6803	.72	.5814	.97	.5076
.23	.8130	.48	.6757	.73	.5780	.98	.5051
.24	.8065	.49	.6711	74	.5747	.99	.5025
.25	.8000	.50	.6667	.75	.5714	1.00	.5000

$$I = \frac{M}{M + m}$$

I = Impact = Percent of Live Load.
M = Maximum stress.
m = Minimum stress.

Coefficients of Impact when there is a reversal of stress.

$\frac{L}{G}$	Percent of Live Load	$\frac{L}{G}$	Percent of Live Load	$\frac{L}{G}$	Percent of Live Load	$\frac{L}{G}$	Percent of Live Load
.00	1 00						
.01	1.02	.26	1.52	.51	2.02	.76	2.52
.02	1.04	.27	1.54	.52	2.04	.77	2.54
.03	1.06	.28	1.56	.53	2.06	.78	2.56
.04	1.08	.29	1.58	.54	2.08	.79	2.58
.05	1.10	.30	1.60	.55	2.10	.80	2.60
.06	1.12	.31	1.62	.56	2.12	.81	2.62
.07	1.14	.32	1.64	.57	2.14	.82	2 64
.08	1.16	.33	1.66	.58	2.16	.83	2.66
.09	1.18	.34	1.68	.59	2.18	.84	2.68
.10	1.20	.35	1.70	.60	2'20	.85	2.70
.11	1 22	.36	1.72	.61	2.22	.86	2.72
.12	1.24	.37	1.74	.62	2.24	.87	2.74
.13	1.26	.38	1.76	.63	2.26	.88	2.76
.14	1.28	.39	1.78	.64	2 28	.89	2.78
.15	1.30	.40	1.80	.65	2.30	.90	2.80
.16	1.32	.41	1.82	.66	2.32	.91	2.82
.17	1.34	.42	1.84	.67	2.34	.92	2.84
.18	1.36	.43	1.86	.68	2.36	.93	2.86
.19	1.38	.44	1.88	.69	2.38	.94	2.88
.20	1.40	.45	1.90	.70	2.40	.95	2.90
.21	1.42	.46	1.92	.71	2.42	.96	2.92
.22	1.44	.47	1.94	.72	2.44	.97	2.94
.23	1.46	.48	1.96	.73	2.46	.98	2.96
.24	1.48	.49	1.98	.74	2.48	.99	2.98
.25	1.50	.50	2.00	.75	2.50	1.00	3.00

$$I = 1 + 2\frac{L}{G}$$

I = Impact = Percent of Live Load
L = Maximum stress of lesser kind.
G = Maximum stress of greater kind.

Allowed Stress per square inch in Compression.

$\frac{l}{r}$	F	$\frac{l}{r}$	F	$\frac{l}{r}$	F	$\frac{l}{r}$	F
1	15933	31	13933	61	11933	91	9933
2	15867	32	13867	62	11867	92	9867
3	15800	33	13800	63	11800	93	9800
4	15733	34	13733	64	11733	94	9733
5	15667	35	13667	65	11667	95	9667
6	15600	36	13600	66	11600	96	9600
7	15533	37	13533	67	11533	97	9533
8	15467	38	13467	68	11467	98	9467
9	15400	39	13400	69	11400	99	9400
10	15333	40	13333	70	11333	100	9333
11	15267	41	13267	71	11267	101	9267
12	15200	42	13200	72	11200	102	9200
13	15133	43	13133	73	11133	103	9133
14	15067	44	13067	74	11067	104	9067
15	15000	45	13000	75	11000	105	9000
16	14933	46	12933	76	10933	106	8933
17	14867	47	12867	77	10867	107	8867
18	14800	48	12800	78	10800	108	8800
19	14733	49	12733	79	10733	109	8733
20	14667	50	12667	80	10667	110	8667
21	14600	51	12600	81	10600	111	8600
22	14533	52	12533	82	10533	112	8533
23	14467	53	12467	83	10467	113	8467
24	14400	54	12400	84	10400	114	8400
25	14333	55	12333	85	10333	115	8333
26	14267	56	12267	86	10267	116	8267
27	14200	57	12200	87	10200	117	8200
28	14133	58	12133	88	10133	118	8133
29	14067	59	12067	89	10067	119	8067
30	14000	60	12000	90	10000	120	8000

$$F = 16000 - 66\tfrac{2}{3}\,\frac{l}{r}$$

F = Allowed stress per sq. in.
l = Length in inches
r = Radius of gyration.

Allowed Stress per square inch in Compression.

$\frac{L}{r}$	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
0.0	16000	15200	14400	13600	12800	12000	11200	10400	9600	8800	8000	7200
.1	15920	15120	14320	13520	12720	11920	11120	10320	9520	8720	7920	7120
.2	15840	15040	14240	13440	12640	11840	11040	10240	9440	8640	7840	7040
.3	15760	14960	14160	13360	12560	11760	10960	10160	9360	8560	7760	6960
.4	15680	14880	14080	13280	12480	11680	10880	10080	9280	8480	7680	6880
.5	15600	14800	14000	13200	12400	11600	10800	10000	9200	8400	7600	6800
.6	15520	14720	13920	13120	12320	11520	10720	9920	9120	8320	7520	6720
.7	15440	14640	13840	13040	12240	11440	10640	9840	9040	8240	7440	6640
.8	15360	14560	13760	12960	12160	11360	10560	9760	8960	8160	7360	6560
.9	15280	14480	13680	12880	12080	11280	10480	9680	8880	8080	7280	6480

$$F = 16000 - 800 \frac{L}{r}$$

F = Allowed stress per sq. in
L = Length in feet
r = Radius of gyration.

Maximum Bending Moments in Pins.

Extreme fiberstress = 24000 lbs per sq. in.

Diam.	Area	Moment in Inch pounds	Diam.	Area	Moment in Inch pounds	Diam.	Area	Moment in Inch pounds
1	.785	2350	$4\frac{3}{8}$	15.033	197300	$7\frac{3}{4}$	47.173	1096800
$1\frac{1}{8}$	.994	3360	$4\frac{1}{2}$	15.904	214800	$7\frac{7}{8}$	48.707	1150800
$1\frac{1}{4}$	1.227	4600	$4\frac{5}{8}$	16.800	233100	8	50.265	1206300
$1\frac{3}{8}$	1.485	6125	$4\frac{3}{4}$	17.721	252500	$8\frac{1}{8}$	51.849	1263800
$1\frac{1}{2}$	1.767	7950	$4\frac{7}{8}$	18.665	272600	$8\frac{1}{4}$	53.456	1323100
$1\frac{5}{8}$	2.074	10100	5	19.635	294500	$8\frac{3}{8}$	55.088	1384100
$1\frac{3}{4}$	2.405	12700	$5\frac{1}{8}$	20.629	317200	$8\frac{1}{2}$	56.745	1447000
$1\frac{7}{8}$	2.761	15600	$5\frac{1}{4}$	21.648	341000	$8\frac{5}{8}$	58.426	1511800
2	3.142	18800	$5\frac{3}{8}$	22.691	365900	$8\frac{3}{4}$	60.132	1578400
$2\frac{1}{8}$	3.547	22700	$5\frac{1}{2}$	23.758	392000	$8\frac{7}{8}$	61.862	1647100
$2\frac{1}{4}$	3.976	26900	$5\frac{5}{8}$	24.850	419300	9	63.617	1717600
$2\frac{3}{8}$	4.430	31600	$5\frac{3}{4}$	25.967	447900	$9\frac{1}{8}$	65.397	1790200
$2\frac{1}{2}$	4.909	36900	$5\frac{7}{8}$	27.109	477800	$9\frac{1}{4}$	67.201	1864800
$2\frac{5}{8}$	5.412	42600	6	28.274	509000	$9\frac{3}{8}$	69.029	1941400
$2\frac{3}{4}$	5.940	49000	$6\frac{1}{8}$	29.465	541400	$9\frac{1}{2}$	70.882	2020100
$2\frac{7}{8}$	6.492	56000	$6\frac{1}{4}$	30.680	575200	$9\frac{5}{8}$	72.760	2101000
3	7.069	63600	$6\frac{3}{8}$	31.919	610500	$9\frac{3}{4}$	74.662	2183900
$3\frac{1}{8}$	7.670	71900	$6\frac{1}{2}$	33.183	647000	$9\frac{7}{8}$	76.590	2269000
$3\frac{1}{4}$	8.296	80900	$6\frac{5}{8}$	34.472	685200	10	78.54	2356200
$3\frac{3}{8}$	8.946	90600	$6\frac{3}{4}$	35.785	724600	$10\frac{1}{4}$	82.52	2537400
$3\frac{1}{2}$	9.621	100700	$6\frac{7}{8}$	37.122	765600	$10\frac{1}{2}$	86.59	2727600
$3\frac{5}{8}$	10.321	112200	7	38.485	808200	$10\frac{3}{4}$	90.76	2927100
$3\frac{3}{4}$	11.045	124200	$7\frac{1}{8}$	39.871	852300	11	95.03	3136100
$3\frac{7}{8}$	11.793	137100	$7\frac{1}{4}$	41.282	897900	$11\frac{1}{4}$	99.40	3355400
4	12.566	150800	$7\frac{3}{8}$	42.718	945100	$11\frac{1}{2}$	103.87	3583500
$4\frac{1}{8}$	13.364	165400	$7\frac{1}{2}$	44.179	994000	$11\frac{3}{4}$	108.43	3822200
$4\frac{1}{4}$	14.186	180900	$7\frac{5}{8}$	45.664	1044600	12	113.10	4071600

Shearing and Bearing Values for Rivets.

Shearing = 12000 lbs. per sq. in.
Bearing = 24000 " " " "

Diam. of Rivet		Area of	Single	Double	Bearing Values for thicknesses of Plates of									
Fract.	Decimal	Rivet	Shear.	Shear	1/4"	5/16"	3/8"	7/16"	1/2"	9/16"	5/8"	11/16"	3/4"	13/16"
3/8	.3750	.1104	1324	2648	2250	2813								
7/16	.4375	.1503	1804	3608	2625	3281	3937							
1/2	.5000	.1963	2356	4712	3000	3750	4500	5250						
9/16	.5625	.2485	2982	5964	3375	4219	5063	5906	6750					
5/8	.6250	.3068	3681	7362	3750	4688	5625	6562	7500					
11/16	.6875	.3712	4454	8908	4125	5156	6188	7219	8250	9281				
3/4	.7500	.4418	5302	10604	4500	5626	6751	7876	9001	10126	11251			
13/16	.8125	.5185	6222	12444	4875	6094	7312	8531	9750	10968	12187	13406		
7/8	.8750	.6013	7216	14432	5250	6563	7875	9188	10500	11813	13126	14438		
15/16	.9375	.6903	8284	16568	5625	7031	8437	9844	11250	12656	14062	15469	16875	
1	1.000	.7854	9425	18850	6000	7500	9000	10500	12000	13500	15000	16500	18000	19500

Safe Resistance against Buckling of Webs per foot run

F = Total Shear.
D = Depth c. to c. Flange rivets. —— which must not be less than $\frac{F}{D}$
t = Thickness of Web.
d = Clear horizontal or vertical distance between angles in inches.

Shear per foot run $= \frac{F}{D} \leq \left(16000 - 100\frac{d}{t}\right)12\,t.$

Least hor. or vert. dist. in clear between Ls.	t = 1/4"			t = 5/16"			t = 3/8"			t = 7/16"			t = 1/2"			t = 9/16"		
	$\frac{d}{t}$	$16000-100\frac{d}{t}$	Safe thrust	$\frac{d}{t}$	$16000-100\frac{d}{t}$	Safe thrust	$\frac{d}{t}$	$16000-100\frac{d}{t}$	Safe thrust	$\frac{d}{t}$	$16000-100\frac{d}{t}$	Safe thrust	$\frac{d}{t}$	$16000-100\frac{d}{t}$	Safe thrust	$\frac{d}{t}$	$16000-100\frac{d}{t}$	Safe thrust
1'-0"	48	11200	33600	38.4	12160	45600	32	12800	57600	27.4	13260	69615	24	13600	81600	21.3	13870	93623
1'-3"	60	10000	30000	48.0	11200	42000	40	12000	54000	34.3	12570	65993	30	13000	78000	26.7	13330	89978
1'-6"	72	8800	26400	57.6	10240	38400	48	11200	50400	41.1	11890	62423	36	12400	74400	32.0	12800	86400
1'-9"	84	7600	22800	67.2	9280	34800	56	10400	46800	48.0	11200	58800	42	11800	70800	37.3	12270	82823
2'-0"	96	6400	19200	76.8	8320	31200	64	9600	43200	54.9	10510	55178	48	11200	67200	42.7	11730	79178
2'-3"	108	5200	15600	86.4	7360	27600	72	8800	39600	61.7	9830	51608	54	10600	63600	48.0	11200	75600
2'-6"	120	4000	12000	96.0	6400	24000	80	8000	36000	68.6	9140	47985	60	10000	60000	53.3	10670	72023
2'-9"	132	2800	8400	105.6	5440	20400	88	7200	32400	75.4	8460	44415	66	9400	56400	58.7	10130	68378
3'-0"	144	1600	4800	115.2	4480	16800	96	6400	28800	82.3	7770	40793	72	8800	52800	64.0	9600	64800
3'-6"				134.4	2560	9600	112	4800	21600	96.0	6400	33600	84	7600	45600	74.7	8530	57578
4'-0"				153.6	640	2400	128	3200	14400	109.7	5030	26408	96	6400	38400	85.3	7470	50423
4'-6"							144	1600	7200	123.4	3660	19215	108	5200	31200	96.0	6400	43200
5'-0"							160	00	00	137.1	2290	12023	120	4000	24000	106.7	5330	35978
5'-6"										150.9	910	4778	132	2800	16800	117.3	4270	28823
6'-0"													144	1600	9600	128.0	3200	21600
6'-6"													156	400	2400	138.7	2130	14378
7'-0"																149.3	1070	7223
7'-6"																160.0	00	00

UNIT STRESSES FOR TIMBER POSTS

$\frac{L}{d}$	Highway Bridges and Buildings		R. R. Bridges
	Yellow Pine	White Pine	Yellow Pine
	$1075-138\frac{L}{d}$	$675-107\frac{L}{d}$	$860-110\frac{L}{d}$
	POUNDS	Per square Inch.	
Dif. 0.1	14	11	11
1.0	937	568	750
1.1	924	557	739
1.2	910	546	728
1.3	896	535	717
1.4	882	524	706
1.5	868	513	695
1.6	855	502	684
1.7	841	491	673
1.8	827	480	662
1.9	813	470	651
2.0	799	460	640
2.1	786	450	629
2.2	772	439	618
2.3	758	428	607
2.4	744	417	596
2.5	730	406	585
2.6	717	395	574
2.7	703	384	563
2.8	689	374	552
2.9	675	364	541
3.0	661	354	530
3.1	647	343	519
3.2	633	332	508
3.3	619	321	497
3.4	605	311	486

L = Length of Member in feet
d = Least dimension of Member in inches.

TIMBER BEAMS OR JOISTS

Capacity in Bending Moments (Foot Pounds) for 1000 Pounds Per Square Inch, Fiber Strain For Railroad Bridges

Width Inches	DEPTH OF BEAM IN INCHES											
	6	7	8	9	10	12	14	15	16	18	20	24
2	1000	1361	1778	2250	2778	4000	5444	6250	. .	. .	. .	. .
2½	1250	1701	2222	2813	3472	5000	6806	7813	8889	. .	. .	. .
3	1500	2042	2667	3375	4167	6000	8167	9375	10667	13500	. .	. .
3½	1750	2382	3111	3938	4861	7000	9528	10938	12444	15750	19444	. .
4	2000	2722	3556	4500	5556	8000	10889	12500	14222	18000	22222	32000
4½	2250	3062	4000	5063	6250	9000	12250	14063	16000	20250	25000	36000
5	2500	3403	4444	5625	6944	10000	13611	15625	17778	22500	27778	40000
5½	2750	3743	4889	6188	7639	11000	14972	17188	19556	24750	30556	44000
6	3000	4083	5333	6750	8333	12000	16333	18750	21333	27000	33333	48000
7	. .	4764	6222	7875	9722	14000	19056	21875	24889	31500	38889	56000
8	. .	. .	7111	9000	11111	16000	21778	25000	28444	36000	44444	64000
9	. .	. .	. .	10125	12500	18000	24500	28125	32000	40500	50000	72000
10	. .	. .	. .	. .	13889	20000	27222	31250	35556	45000	55556	80000
12	. .	. .	. .	. .	. .	24000	32667	37500	42667	54000	66667	96000

Timber Beams or Joists.

Capacity in Bending Moments (Foot Pounds) for 1200 pounds per square inch fiber strain.

Width Inches	Depth of beam in inches.											
	6	7	8	9	10	12	14	15	16	18	20	24
2	1200	1633	2133	2700	3333	4800						
2½	1500	2042	2667	3375	4167	6000	8167					
3	1800	2450	3200	4050	5000	7200	9800	11250				
3½	2100	2858	3733	4725	5833	8400	11433	13125	14933			
4	2400	3267	4267	5400	6667	9600	13067	15000	17067	21600		
4½	2700	3675	4800	6075	7500	10800	14700	16875	19200	24300		
5	3000	4083	5333	6750	8333	12000	16333	18750	21333	27000	33333	
5½	3300	4492	5867	7425	9167	13200	17967	20625	23467	29700	36667	
6	3600	4900	6400	8100	10000	14400	19600	22500	25600	32400	40000	57600
7		5717	7467	9450	11667	16800	22867	26250	29867	37800	46667	67200
8			8533	10800	13333	19200	26133	30000	34133	43200	53333	76800
9				12150	15000	21600	29400	33750	38400	48600	60000	86400
10					16667	24000	32667	37500	42667	54000	66667	96000
12						28800	39200	45000	51200	64800	80000	115200

ESTIMATED WEIGHTS OF STEEL SUPERSTRUCTURES FOR BRIDGE SPANS

SPAN IN FEET	WEIGHT IN POUNDS	
	PER FOOT.	PER SPAN.
DECK PLATE GIRDERS		SINGLE TRACK.
OUT TO OUT = L	14.2L + 140	$14.2L^2 + 140L$
35	637.5	22,300
50	849.6	42,480
65	1,063.0	69,100
80	1,275.0	102,000
95	1,489.0	141,450
THROUGH RIVETED SINGLE TRACK SPANS-SUBDIVIDED WARREN TRUSSES.		
CENTER TO CENTER = L	11L + 800	$11L^2 + 800L$
100	1,900.	190,000
110	2,010.	221,100
120	2,120.	254,400
125	2,180.	272,500
130	2,229.	289,900
140	2,339.	327,600
150	2,450.	367,500
160	2,560.	409,600
170	2,668.	453,900
175	2,736.	478,500
180	2,780.	500,400
190	2,887.	549,100
200	3,000.	600,000

This table was prepared for E 50 loading under specifications that give slightly heavier girders than those of these specifications, and above weights include fillers under all stiffeners.